

## THE HEAVY SNOWSTORM OF MARCH 18-19, 1956

### The Climax of a Record Late-Season Snow Accumulation in Southern New England

Conrad P. Mook and Kenneth S. Norquest

U. S. Weather Bureau Forecast Center, Washington National Airport, Washington, D. C.

#### 1. INTRODUCTION

The month of March 1956 was characterized by a series of late-season heavy snowstorms along the northeastern Atlantic coast of the United States. This report presents the results of a study of the meteorological conditions leading up to and attending the record-breaking snowstorm of March 18 and 19. This storm was the last of a series and presented unusual features which contributed to the difficulty of the forecast problem. The two storms within the 6 days preceding are discussed briefly to show the typical pattern of development of many east-coast snowstorms, and thus to furnish a background to reveal the contrasting features found in the present study.

#### 2. ANTECEDENT CONDITIONS

On Friday, March 16, 1956, by 1230 GMT the stage was set for the typical development of a coastal Low which gives heavy snow and high winds in the Northeast. The North Atlantic States had been flooded with cold air due to eastward passage of a 1032-mb. High from the Great Lakes region to Maine. Meanwhile, a wave, which developed in the West Gulf on the trailing polar front, had deepened and moved northeastward to eastern Kentucky. This was attended by widespread heavy rains in the Southeastern States and snow through the Ohio Valley eastward to southern New Jersey. By this time the typical pattern of development was evident. A warm front lay along the Carolina coast, then extended eastward north of Bermuda. An area of 3-hourly pressure falls, of 4 to 5 mb. concentrated in eastern North Carolina and southeastern Virginia, strongly indicated a secondary development on the coast [5]. By 0030 GMT, March 17, 12 hours later, the low center in eastern Kentucky had entirely filled and the secondary Low had formed and deepened to 984 mb. just off Atlantic City, N. J. The pressure at Atlantic City fell 25 mb. in just 12 hours, indicating the explosive nature of the cyclogenesis which took place. Snow had now spread over all of the North Atlantic States, attended by strong winds with gales on the coast. By 0630 GMT, March 17, the center was 970 mb. just east of Nantucket. Snow and strong winds covered the Northeastern States and gales continued on the New England coast. By 1230 GMT, March 17, the storm was well out to sea some 380 miles east of Boston.

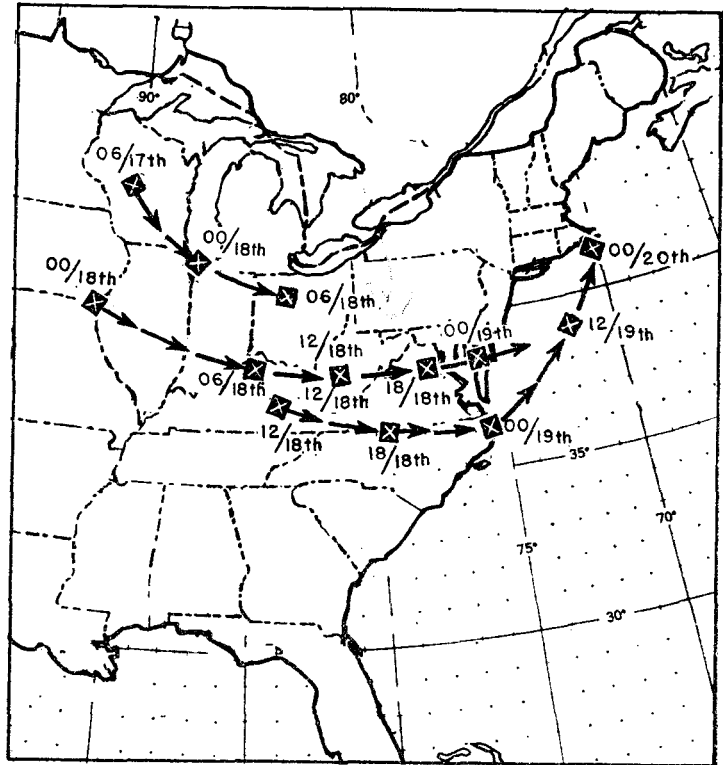


FIGURE 1.—Detailed track of Low associated with snowstorm of March 18-19, 1956.

This storm was a nearly perfect example of the rapid development of a coastal storm wherein high-level divergence is suddenly superimposed over a noncompensating warm sector in the manner described by Petterssen et al. [8]. It deposited 14 inches of new snow for a total depth of 20 inches at Albany, N. Y. It added 6 inches for a total of 10 inches at Hartford, Conn., and 10 inches for a total depth of 24 inches at Concord, N. H. New York City and Boston, Mass., were left with 5 and 7 inches of new snow, respectively.

It is important to note that this storm moved at a rate of 43 knots, passing just south of Nantucket. In 12 hours it moved from a position off the coast near Atlantic City to 380 miles east of Boston.

A similar but less explosive example occurred just 2 days previously, on March 14, 1956. This was the first of the series of three snowstorms which visited New York and

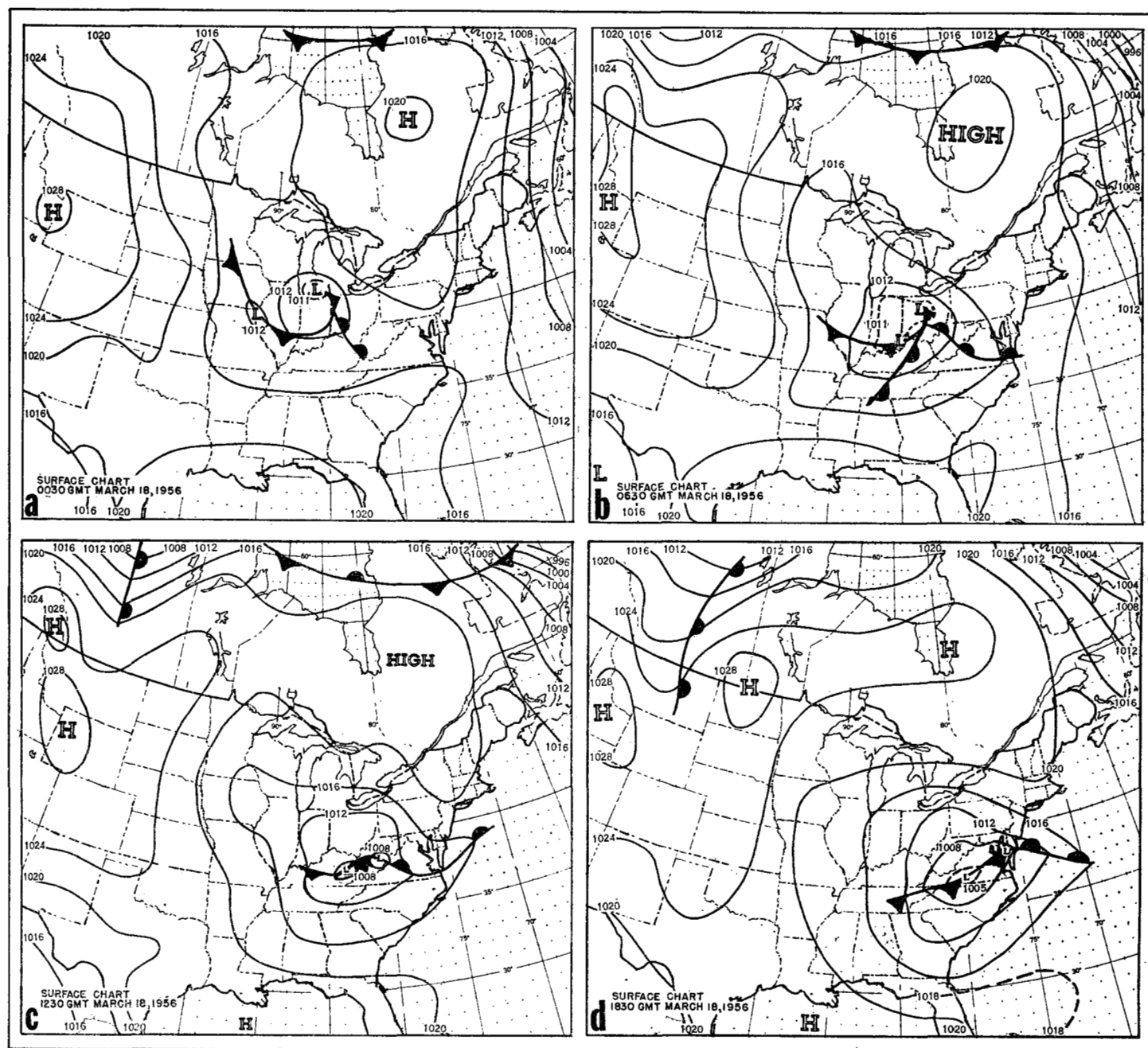


FIGURE 2.—Sea level synoptic charts for March 18, 1956. (A) 0030 GMT, (B) 0630 GMT, (C) 1230 GMT, (D) 1830 GMT.

New England in 6 days. The first two were typical developments which meteorologists have learned to handle fairly well. The third of the series was unusual and is the subject of this paper.

### 3. CHARACTERISTICS OF THE SNOW OF MARCH 18-19

By early morning of the 18th (1230 GMT) the area of snowfall attending the developing southern low centers over eastern Kentucky and southern West Virginia (fig. 2C) had enlarged to cover the Ohio Valley and had spread eastward over the Appalachians to cover Pennsylvania, southern New Jersey, Maryland west of Chesapeake Bay,

and western and northern Virginia. Measurable amounts of snow had fallen only as far east as Harrisburg, Pa., and the Roanoke-Lynchburg area of Virginia.

By early afternoon of the 18th, 1830 GMT, (fig. 2D), precipitation covered the Middle Atlantic States from New York City to Norfolk, Va., and extended westward through West Virginia to Cincinnati, Ohio. Precipitation fell as rain over southern Maryland and southern Virginia, while snow was falling over the remainder. Snow had spread from southern New Jersey, beginning at 1545 GMT at Newark and 1603 GMT at New York City. At this time one low center was moving eastward near

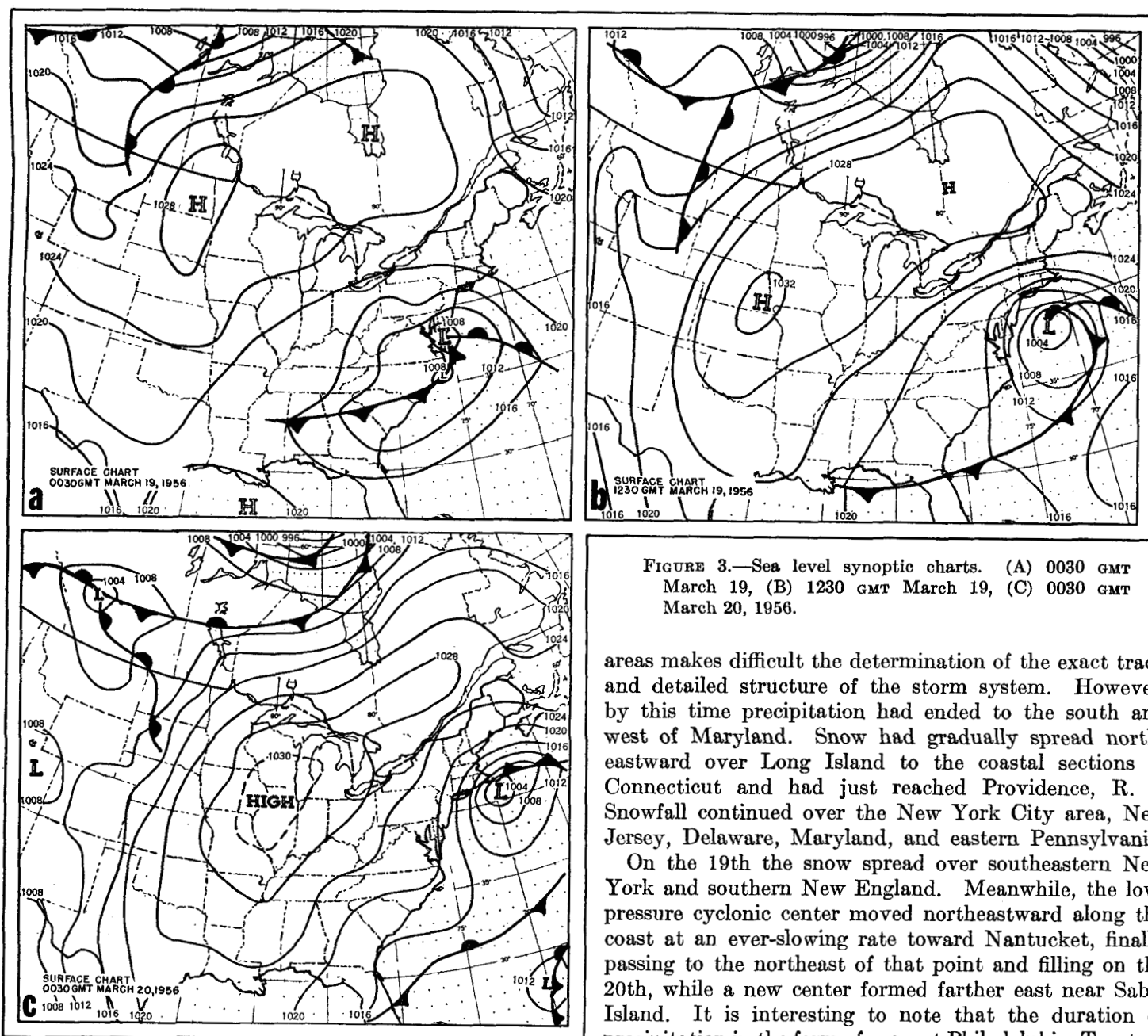


FIGURE 3.—Sea level synoptic charts. (A) 0030 GMT March 19, (B) 1230 GMT March 19, (C) 0030 GMT March 20, 1956.

areas makes difficult the determination of the exact track and detailed structure of the storm system. However, by this time precipitation had ended to the south and west of Maryland. Snow had gradually spread north-eastward over Long Island to the coastal sections of Connecticut and had just reached Providence, R. I. Snowfall continued over the New York City area, New Jersey, Delaware, Maryland, and eastern Pennsylvania.

On the 19th the snow spread over southeastern New York and southern New England. Meanwhile, the low-pressure cyclonic center moved northeastward along the coast at an ever-slowing rate toward Nantucket, finally passing to the northeast of that point and filling on the 20th, while a new center formed farther east near Sable Island. It is interesting to note that the duration of precipitation in the form of snow at Philadelphia, Trenton, Atlantic City, Newark, and New York City (Battery) ranged from 31 hours at Philadelphia to 35 hours at Atlantic City. Farther east, over southern New England, the duration ranged from 26 hours at New Haven to 24 hours at Boston. In spite of this, however, the depth of new snow added by the storm was remarkably uniform, measuring 12 to 13 inches at Trenton, New York City, New Haven, Bradley Field (Hartford), and Boston. A notable exception was the 18 inches which fell at Newark. There, for a 6-hour period, precipitation occurred at a rate of 0.14 inch per hour (melted). This was three times the hourly rate of 0.05 inch which prevailed for 10 hours prior to and 4 hours immediately following this period of heaviest snow. It is curious to note that at Trenton a uniform rate of around 0.05 inch (melted) was maintained for 20 hours.

Quantico, Va., while another was also moving eastward near Danville, Va.

During the next 6 hours there was little change in the area of precipitation. Showers and thunderstorms moved eastward across southern Virginia and eastern North Carolina as the southern low center moved to the coast near Elizabeth City, N. C., by 0030 GMT (fig. 3A). Snow continued from Maryland and Delaware northward over Pennsylvania and into Long Island as well as westward to Cincinnati, Ohio, as the northern low center moved to southern Delaware.

By 0630 GMT of the 19th (see fig. 3B for 1230 GMT) the surface low system was off the coast, some distance southeast of New Jersey, moving northeastward. Lack of receipt of a sufficient number of reports over the water

The previous storm of Friday night and Saturday, March 16 and 17, had been attended by strong winds and snow with temperatures generally around 20° F. This resulted in heavy drifting which effectively closed roads and highways, as well as many railroads, bringing surface travel to a halt. The present storm on March 18 and 19 added roughly 13 inches of new snow, and the attending high winds caused further drifting and piling up of snow in southern New England and the New York City area before the paralyzing effects of the previous storm could be alleviated. The 18 inches of snow on the ground at Boston on the morning of March 20 (12 inches of which occurred during the 12 hours ending on the evening of the 19th) was the greatest amount of snow on the ground ever recorded in March for that area. On the previous evening all March records for snow on the ground at Hartford, Conn., had been broken. On the night of March 19–20 roads became impassable in many parts of Connecticut, Massachusetts, and Rhode Island, and by morning most forms of transportation again slowed to a standstill. On Long Island some communities were isolated due to heavy drifting.

#### 4. RECONSTRUCTION OF THE CYCLONE TRACK

The tracks of 16 cyclonic centers, which produced 9 or more inches of snow in the Boston area, have been shown by Brooks and Schell [3]. They showed that the typical heavy snowstorm in southern New England is associated with a disturbance which has formed over the South or Middle Atlantic States or the ocean nearby, with the paths of the snow-producing centers passing between 70 and 265 miles south or southeast of Boston. Similar tracks for other east-coast cities, including Philadelphia and New York, were shown by Mook [6].

On March 17, a weak cyclonic center in Wisconsin appeared to be moving southeastward with a course which would carry it far enough north to alleviate any further threat of heavy snow to cities along the east coast. The air in advance of the storm was cold enough for snow, but there appeared to be little moisture available for precipitation even if the storm should be carried southward. An example of the purely objective indications presented by this storm may be found in the 1,000-mb. prognostic charts prepared on an electronic computer by the Joint Numerical Weather Prediction Unit, using a quasi-geostrophic, 3-parameter model and data from 1500 GMT on March 17. By this method one would have expected the Low to be located just northwest of Toledo, Ohio, at 1500 GMT of the 18th and in northwestern Pennsylvania at 0300 GMT of the 19th. Actually, by 0300 GMT of the 19th, heavy snow had already occurred in southeastern Pennsylvania from a developing system off the coast east of Virginia. (See fig. 1.)

At the time of this development it appeared that the Wisconsin Low had suddenly plunged southward after reaching Ohio early on March 18, thereafter following an eastward course through Virginia during the day. The

storm track shown in Chart X of this issue of the *Monthly Weather Review* shows that such a solution is possible, even in retrospect. In this report we attempt to show that this series of events was actually the result of a continuous process by which two successive redevelopments of the storm track to a more southerly position occurred on March 18. An attempt also is made in the following paragraphs to show by what means these events took place.

The gradual southward shift of the storm track, shown in figure 1, should be compared with the sea-level charts for the area shown in figures 2 and 3. In the preparation of these charts, close attention was paid to all transmitted sea level pressure data. At times the pressure gradient was so weak that recourse was made to the construction of isobars at more frequent intervals in the questionable areas. Some of these are shown as dashed, rather than solid lines.

#### 5. THE PROGRESSIVE SOUTHWARD DEVELOPMENT AS RELATED TO THICKNESS PATTERNS

In order to find suggestions regarding the redevelopment which was taking place at 0630 GMT of the 18th (fig. 2B), the thickness patterns, which are prepared by the National Weather Analysis Center at 12-hour intervals for the layers 1,000–500 mb. and 500–300 mb., were examined (figs 4 and 5). On those for 1500 GMT of March 17, we found a rather uniform gradient of 1,000–500-mb. thickness extending northward from the United States through central Canada (fig. 4A), but on the chart showing the thickness of the 500–300-mb. layer (fig. 5A) a nearly closed center was located in southern Canada, extending in a north-northwesterly direction from North Dakota. Twelve hours later, at 0300 GMT of the 18th, the lower layer (fig. 4B) showed a similar configuration to that found at 1500 GMT of the 17th, but the separate center found on the 500–300-mb. thickness charts had become cut off and extended northwestward from Ohio to the eastern Dakotas (fig. 5B).

Also, at the same time, a jet stream with highest winds near the 300-mb. level (not shown) extended southeastward from Montana to South Carolina with a jet maximum, containing winds of greater than 150 knots, lying across central Missouri parallel to the high-level cold air “island”, represented by the closed center on the 500–300-mb. thickness chart (fig. 5B). Note here, however, that the developing sea level cyclone, moving eastward through southern Illinois and Indiana, was not located beneath the jet stream, but rather *its track lay beneath the southern boundary of the closed center on the 500–300-mb. thickness chart*. This observation, therefore, leads us to suggest the following hypothesis regarding the redevelopment of the cyclone farther to the south, between 0030 and 0630 GMT of March 18.

The weather accompanying the northern center had, up until this time, been characterized by small amounts of snowfall and, therefore, presumably relatively low vertical

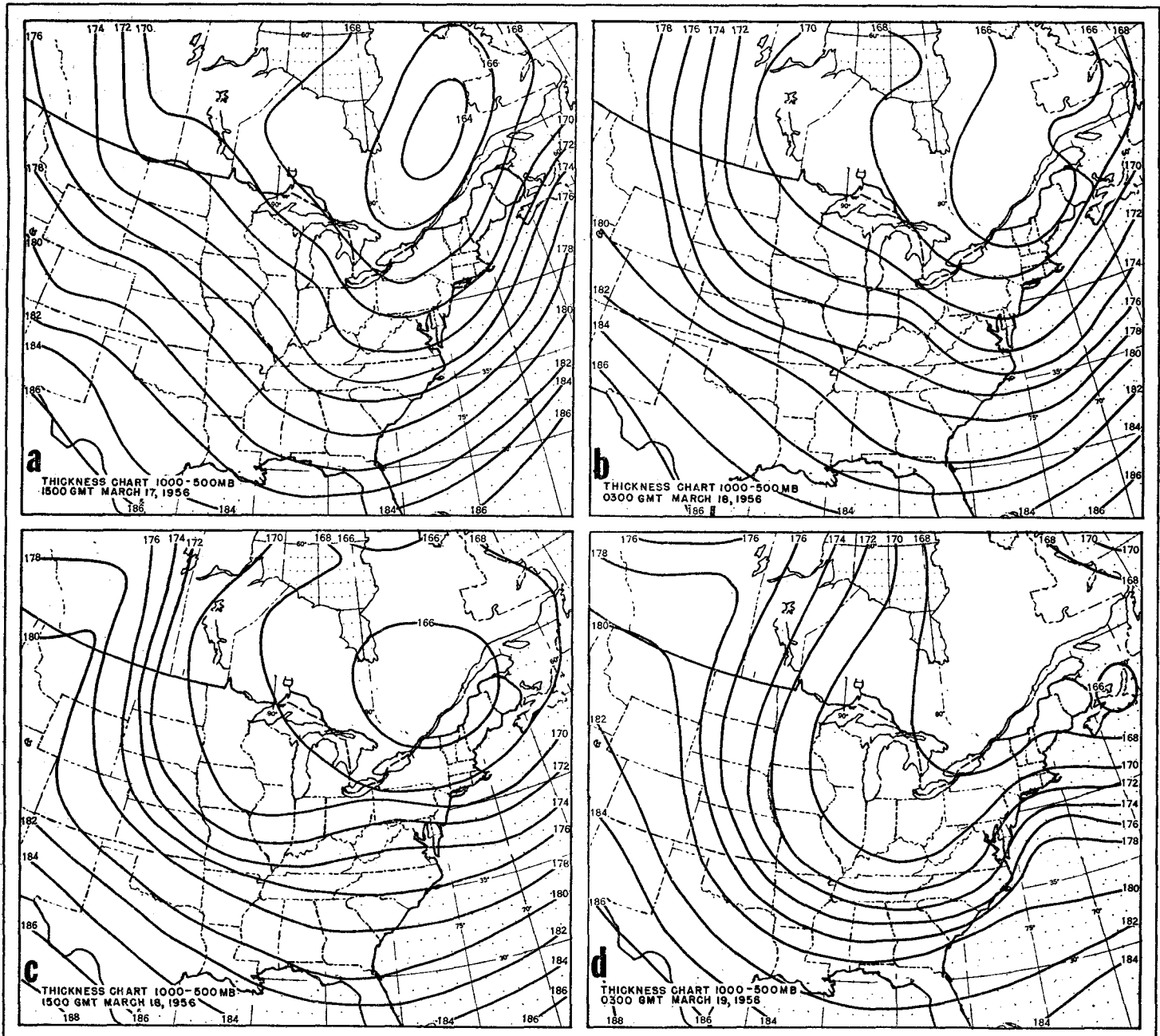


FIGURE 4.—1,000–500-mb. thickness patterns. (A) 1500 GMT, March 17, (B) 0300 GMT, March 18, (C) 1500 GMT, March 18, (D) 0300 GMT, March 19, 1956.

motion speeds. The snow persisted in the wake of the storm path suggesting that there was some lag in the precipitation processes as compared with the movement of the Low. The appearance of the cutoff cold air center over this snow pattern, even though the amounts of snow were small, suggests that this center may have developed, or have been maintained at least in part, by cooling produced by upward vertical air motions. If this is true, we have at hand a mechanism for producing a considerable amount of lateral shear (or vorticity) over the region of new development. The mechanism envisaged here is associated with the often-neglected "twisting" term in the vorticity equation, wherein relatively high-speed air can be trans-

ported downward, and conversely, relatively low-speed air can be transported upward.

The role of this term can be seen in the complete vorticity equation wherein it is the second term on the right:

$$\frac{d\eta}{dt} = -\eta \left( \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} \right) - \left( \frac{\partial \dot{p}}{\partial x} \frac{\partial v}{\partial p} - \frac{\partial \dot{p}}{\partial y} \frac{\partial u}{\partial p} \right)$$

where  $p$  is the vertical coordinate,

$\frac{d\eta}{dt}$  = time rate of change of absolute vorticity

$\dot{p} = \frac{dp}{dt}$ , an approximate measure of vertical motion.



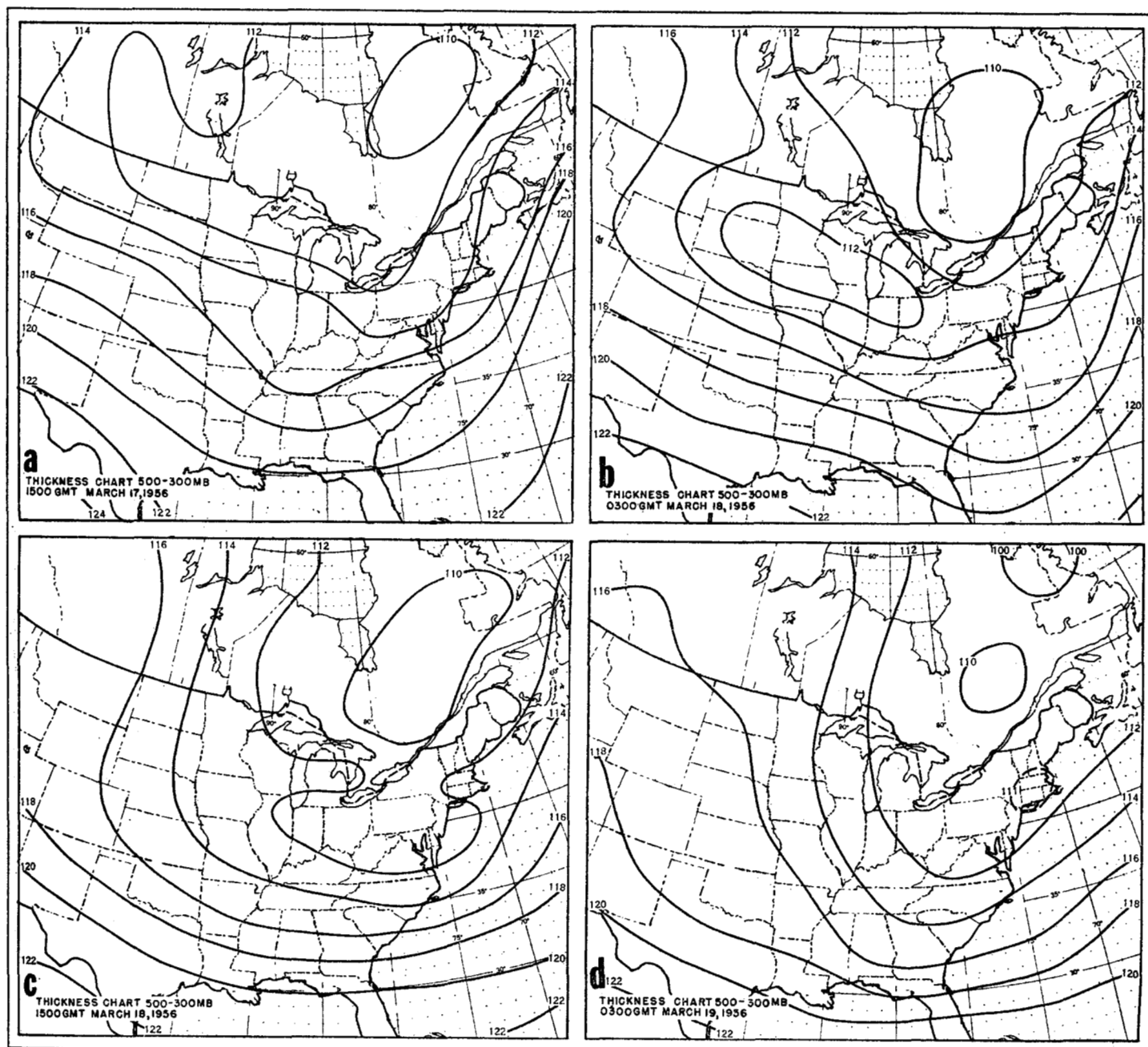


FIGURE 5.—500–300-mb. thickness patterns. (A) 1500 GMT, March 17, (B) 0300 GMT, March 18, (C) 1500 GMT, March 18, (D) 0300 GMT, March 19, 1956.

Though usually neglected, the twisting term may become important at levels where large-scale vertical motions reach a maximum, such as near the level of nondivergence.

Reed and Sanders [9] have applied a twisting term to the study of frontogenesis in the mid-troposphere, and Austin [2] has proclaimed its usefulness in the prediction of trough development at the 500-mb. level in circumstances where the upper-level temperature fields give evidence of its possible application.

A comparison of subsequent 500–300-mb. thickness charts (fig. 5B, C, D) with the storm track (fig. 1) indicates how the Low remained coupled with the southern edge of

the cold center. During this period the jet stream continued well south and southeast of the cyclone center, a situation which Vederman [7] found to exist in only 1 out of 5 Boston snowstorms which he examined.

#### 6. COMPARISON OF THE ROLES OF HIGH-LEVEL DIVERGENCE AND LOW-LEVEL TEMPERATURE ADVECTION IN THE INTENSIFICATION OF THE CYCLONE

At 1500 GMT on March 17, the 12-hour height changes at 500 mb. showed a closed center of falls over eastern Montana and western North Dakota (fig. 6A). The corre-

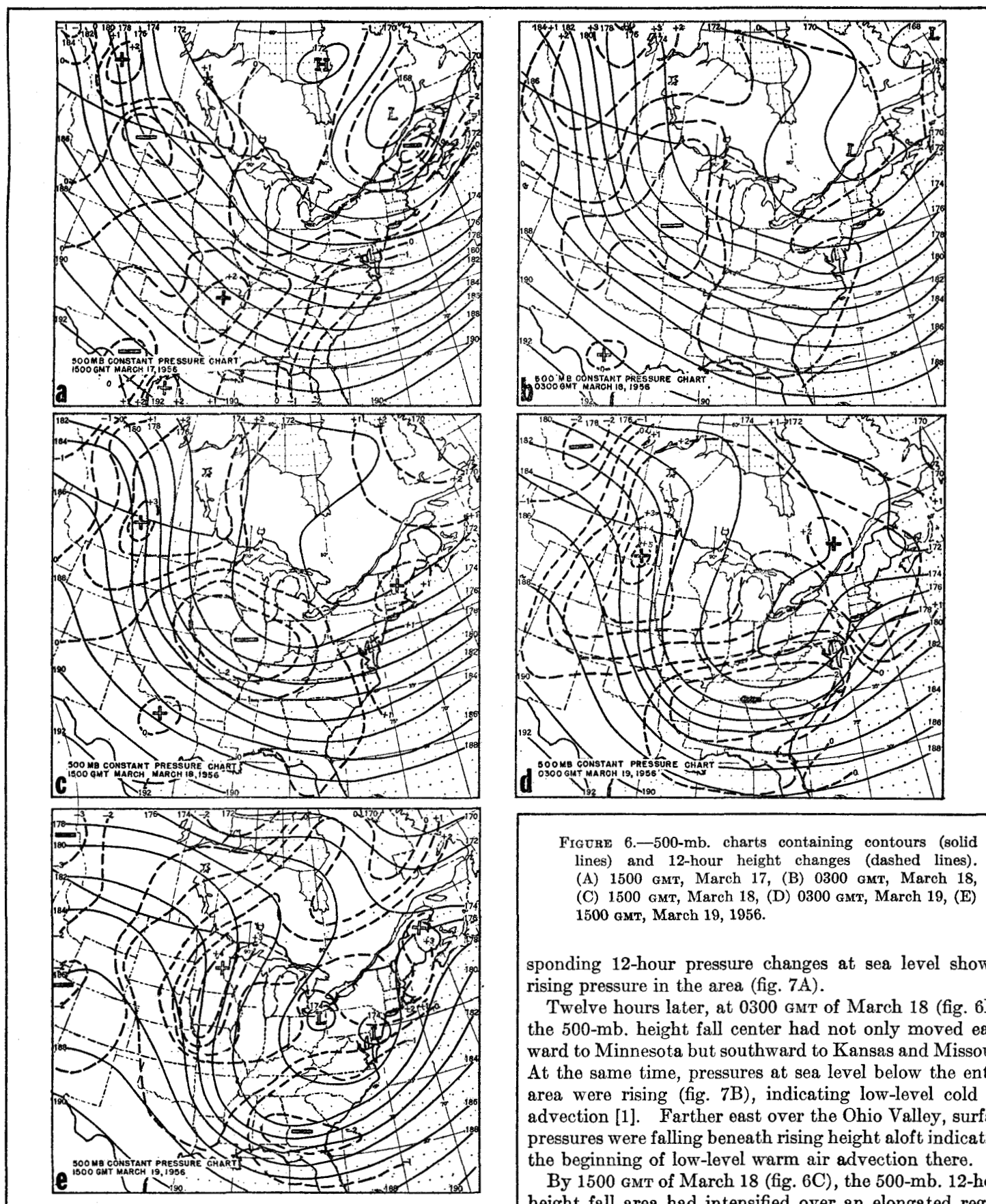


FIGURE 6.—500-mb. charts containing contours (solid lines) and 12-hour height changes (dashed lines). (A) 1500 GMT, March 17, (B) 0300 GMT, March 18, (C) 1500 GMT, March 18, (D) 0300 GMT, March 19, (E) 1500 GMT, March 19, 1956.

sponding 12-hour pressure changes at sea level showed rising pressure in the area (fig. 7A).

Twelve hours later, at 0300 GMT of March 18 (fig. 6B), the 500-mb. height fall center had not only moved eastward to Minnesota but southward to Kansas and Missouri. At the same time, pressures at sea level below the entire area were rising (fig. 7B), indicating low-level cold air advection [1]. Farther east over the Ohio Valley, surface pressures were falling beneath rising height aloft indicating the beginning of low-level warm air advection there.

By 1500 GMT of March 18 (fig. 6C), the 500-mb. 12-hour height fall area had intensified over an elongated region

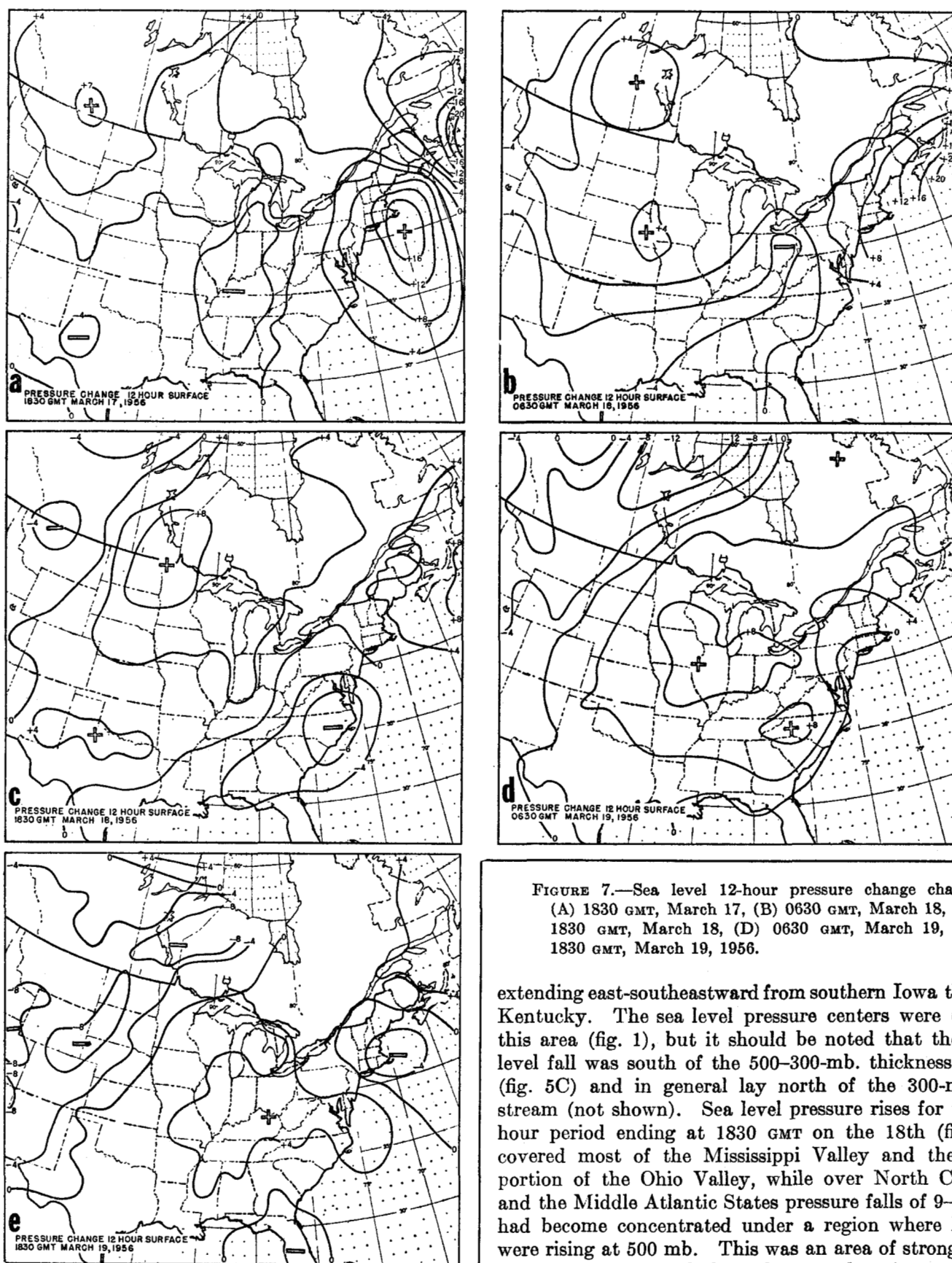


FIGURE 7.—Sea level 12-hour pressure change charts. (A) 1830 GMT, March 17, (B) 0630 GMT, March 18, (C) 1830 GMT, March 18, (D) 0630 GMT, March 19, (E) 1830 GMT, March 19, 1956.

extending east-southeastward from southern Iowa through Kentucky. The sea level pressure centers were east of this area (fig. 1), but it should be noted that the high-level fall was south of the 500–300-mb. thickness center (fig. 5C) and in general lay north of the 300-mb. jet stream (not shown). Sea level pressure rises for the 12-hour period ending at 1830 GMT on the 18th (fig. 7C) covered most of the Mississippi Valley and the lower portion of the Ohio Valley, while over North Carolina and the Middle Atlantic States pressure falls of 9–11 mb. had become concentrated under a region where heights were rising at 500 mb. This was an area of strong warm air advection, particularly in the coastal sections. At this



time height rises at 500 mb. should be noted over New England and the Gulf of St. Lawrence.

By 0300 GMT of March 19 (fig. 6D), the 500-mb. height fall area had moved southeastward, but the sea level 12-hour isallobaric area at 0630 GMT of the 19th (fig. 7D) showed pressure rises over most of the eastern United States. Meanwhile, a center of pressure fall was located off the east coast south of New England. This suggested that as yet only the forward edge of the upper-level pressure fall had reached the surface Low and that the latter would deepen if it became blocked as the upper-level fall area approached. The 500-mb. flow pattern (fig. 6D) indicated that a larger portion of the 500-mb. isallobaric center would be steered into the area, and the surface pattern (fig. 3A and B) indicated an intensification of low-level temperature contrasts as the Low slowed down over the relatively warmer Atlantic coastal waters. With the development of high pressure east of the center at the surface, the Low slowed, moved northeastward, and deepened. The sea level rises, or blocking, east of the low center, may be attributed to 500-mb. height rises in advance of the developing trough, coupled with low-level cold air advection (not shown).

By 1500 GMT of March 19, the flow at 500 mb. (fig. 6E) was from the south over New England, indicating some of the changes which occurred aloft to aid in the intensification of precipitation in the Providence-Boston area. This rapid change in the upper-air flow immediately prior to heavy snow at Boston has been noted previously by Brooks and Schell [4], who utilized the winds on Mt. Washington as an index. Such rapid changes are also an index of the difficulties encountered when forecasting snowfall from such storms.

## 7. THE POSSIBLE ROLE OF LOW-LEVEL INSTABILITY

In the initial stages of this investigation it appeared to the authors that much of the snow may have been due in part to low-level addition of heat and moisture as cold air moved inland following a trajectory over water. Such a process may have been taking place in the earlier stages of the storm wherein it was noted on March 18 that moderate snow began at Atlantic City, N. J., and Philadelphia, Pa., at 1430 GMT, several hours prior to the beginning of snow of similar intensity at Baltimore, Md., and Wilmington, Del. However, in its later stages there was no such indication, and the snow on the 19th must therefore be attributed to the vertical motions normally associated with cyclonic development.

## 8. COMPARISON WITH PRIOR HEAVY SNOWSTORMS AT NEW YORK

An examination of January, February, and March storms, which resulted in more than 11 inches of snow at New York City during the period 1899–1939, reveals that 5 of the 7 reported were preceded by maps of the types shown in figure 8. These two maps are composites of surface isobaric patterns 12 to 24 hours prior to the

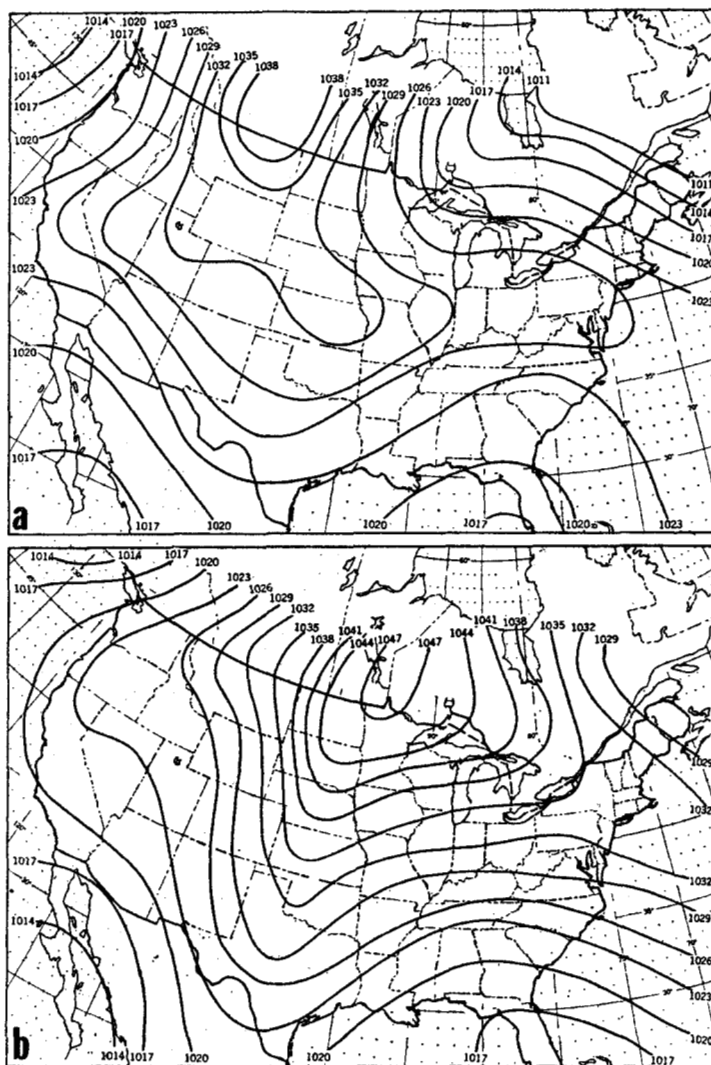


FIGURE 8.—Composite sea level charts showing synoptic patterns 12–24 hours prior to snowstorms producing more than 11 inches of snow at New York City. (A) February 11, 1899, February 28, 1914, and January 22, 1935. (B) February 3, 1920 and February 19, 1921.

beginning of the snow and were constructed by means of a grid applied to the Northern Hemisphere Maps [10]. This configuration of surface isobars has been identified by Weightman [11] as the “neck-of-high” type, and more recently the frontal waves, which are associated with storms resulting from this configuration, have in general been classified by Miller [5] as “Type A” waves.

The two remaining instances, those of January 15, 1910, and February 10, 1926, are somewhat similar to the present case in that a secondary formed in the Hatteras-Virginia Capes region after the primary Low had moved into Ohio from the west or northwest.

## 9. CONCLUSIONS

The heavy snowstorm of March 18–20, 1956, was associated with a sea level low pressure system which developed north of the zone of major divergence aloft, but in a zone where cyclonic vorticity generation and/or fronto-

genesis was likely in the mid-troposphere. The slow and erratic reestablishment of cyclonic activity southeast of the filling center in the Great Lakes region was in part due to the failure of the major upper-level divergence zone, as indicated by the 500-mb. height change center, to come in contact with a major low-level baroclinic zone. Instead, the cyclone formed and intensified in a region where the generation of cyclonic shear in the mid-troposphere was apparently coupled with the gradual generation of a region of low-level temperature contrast.

#### ACKNOWLEDGMENTS

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